Remote Sensing of Crop Development and Evapotranspiration

Lee Johnson
Sr. Research Scientist
CSU Monterey Bay
NASA Ames Research Center
Lee.F.Johnson@nasa.gov

2014 FREP/WPHA Conference

Outline

- Intro/context
- Supporting technologies
- Satellite-based mapping in California
- Example applications

Water resource management challenges

- Competing demands
- Drought impacts
- Water quality and impaired water bodies
- Aging water conveyance infrastructure
- Groundwater overdraft
- Population growth and climate change
- Interaction w/ nitrate mgt

Improving irrigation management

- Agronomic
- Engineering
- Institutional
- Managerial; eg, ET-based scheduling

Howell (2001)

Definitions

- **Evapotranspiration (ET):** Water lost to the atmosphere from combined processes of evaporation from soil/plant surfaces, and transpiration by plant tissues.

- **Reference evapotranspiration (ET_o):** ET from a well-watered reference crop (grass in Calif.)

- **Crop ET (ET_c):** ET from an agricultural crop (basal vs. net)

- **Crop coefficient (K_c):** A unitless coefficient used to convert ET_o to ET_c for a specific crop.

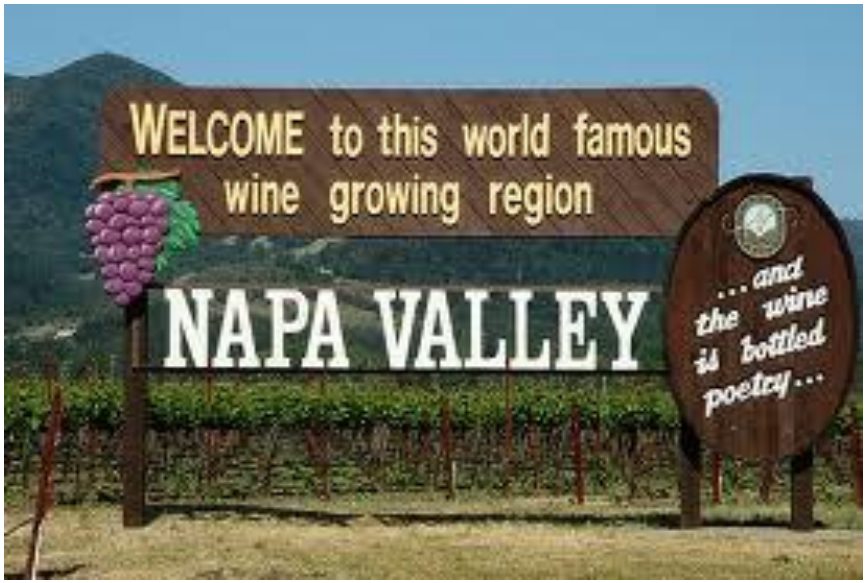
- **Fractional cover**: proportion of field covered by green crop (vs. bare soil) as viewed from above

Basal conditions (ET ≈ potential transpiration)

Well-watered crop, on drip

Non-basal conditions

Bare-soil evaporation



Deficit irrigation (water stress)

Remote sensing of crop ET

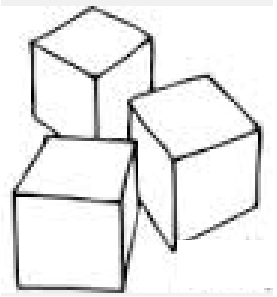
2 main approaches:

- Vegetation index methods (e.g., SIMS)
  - Primarily uses two spectral bands: red & near-infrared
  - Basal conditions (potential transpiration)
  - Optional post-processing via soil water balance model

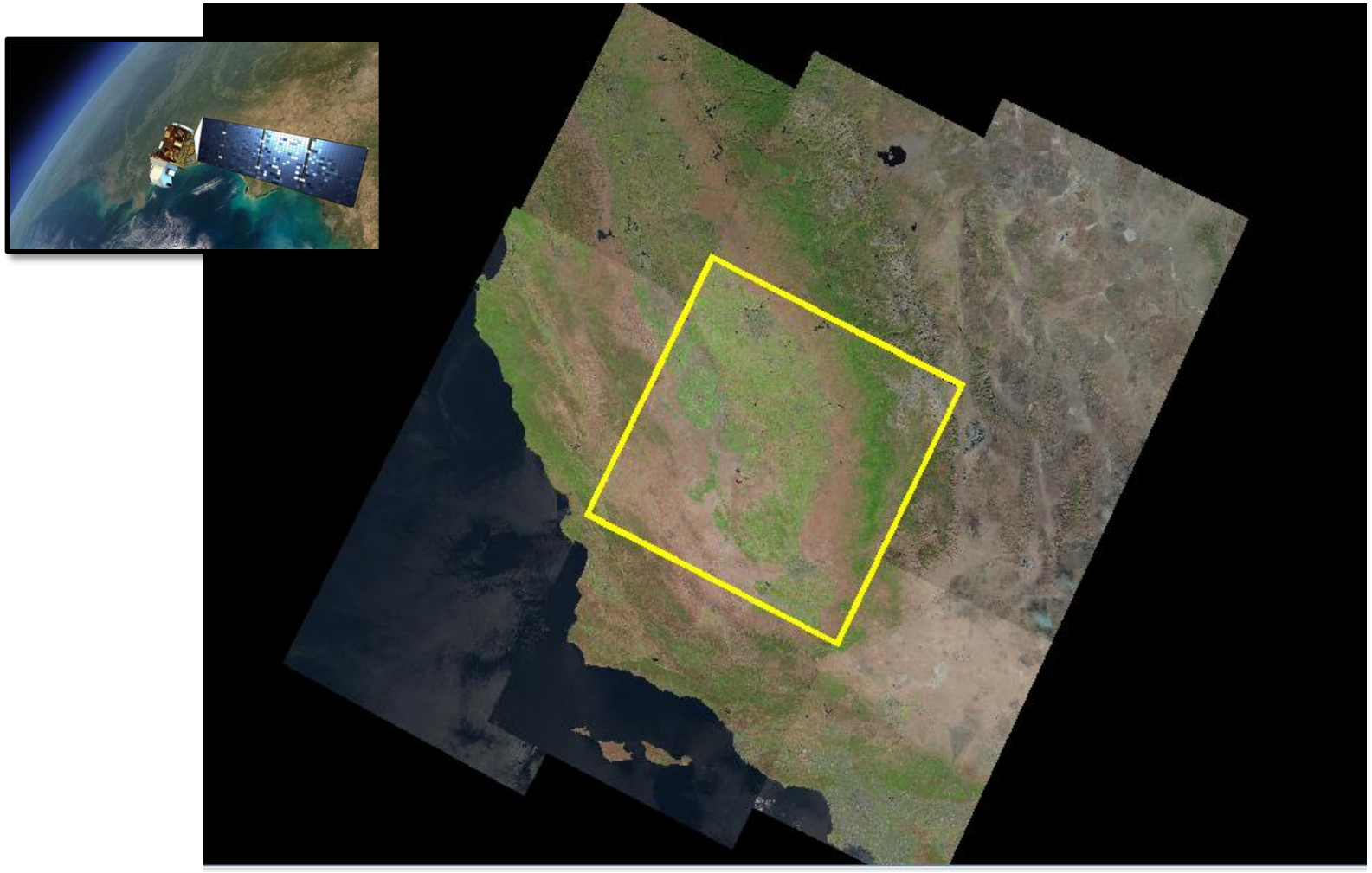
- Surface energy balance methods (SEBAL, METRIC)
  - Uses all spectral bands, including thermal infrared
  - Accounts for crop stress and soil evaporation
  - Automation a continuing challenge

Building blocks

- Landsat system & associated research
- Prior ag-engineering/irrigation research
- CIMIS data availability

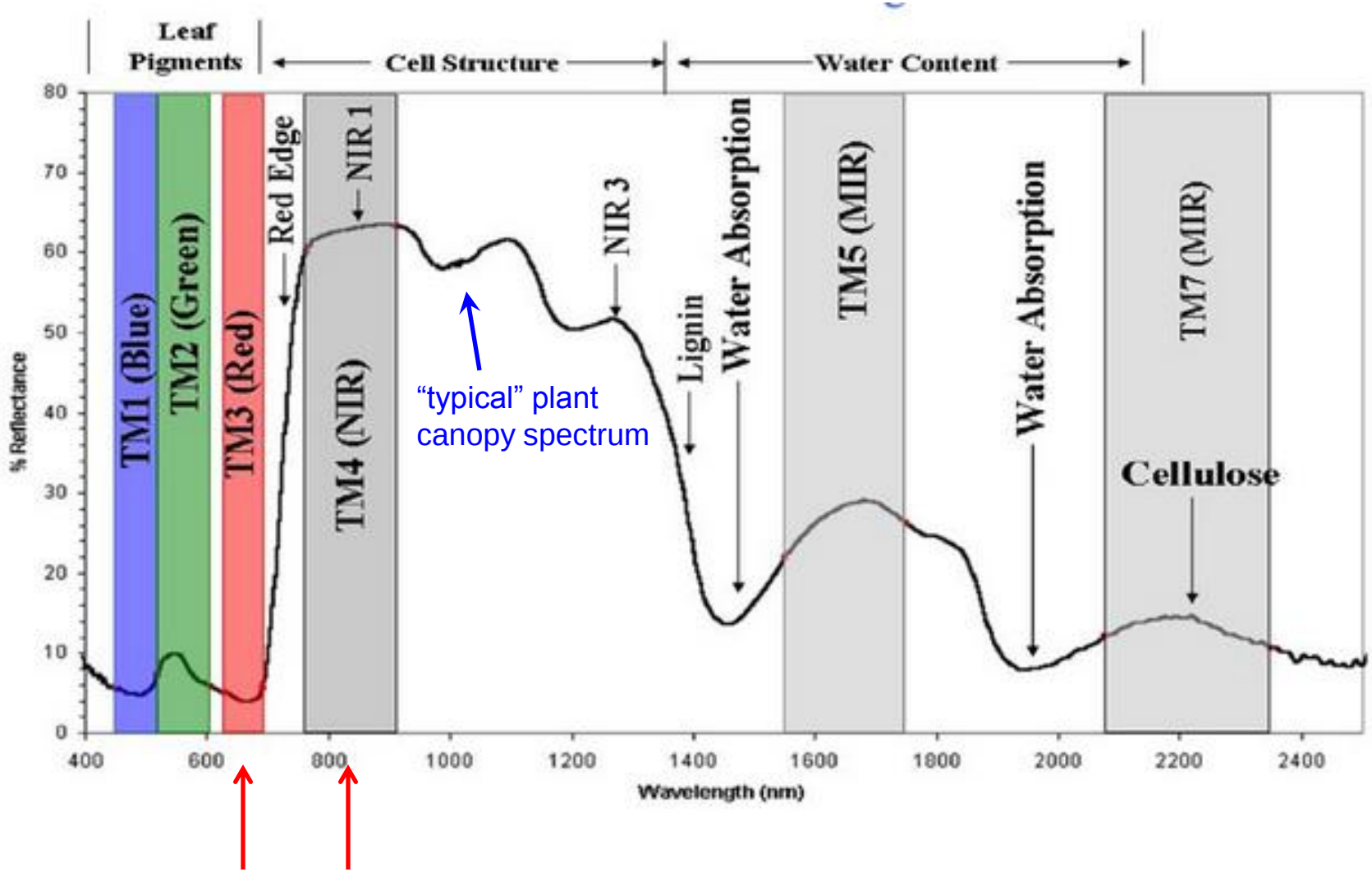


Landsat 7, 8



¼ acre resolution, overpass every 8 days

Landsat spectral bands

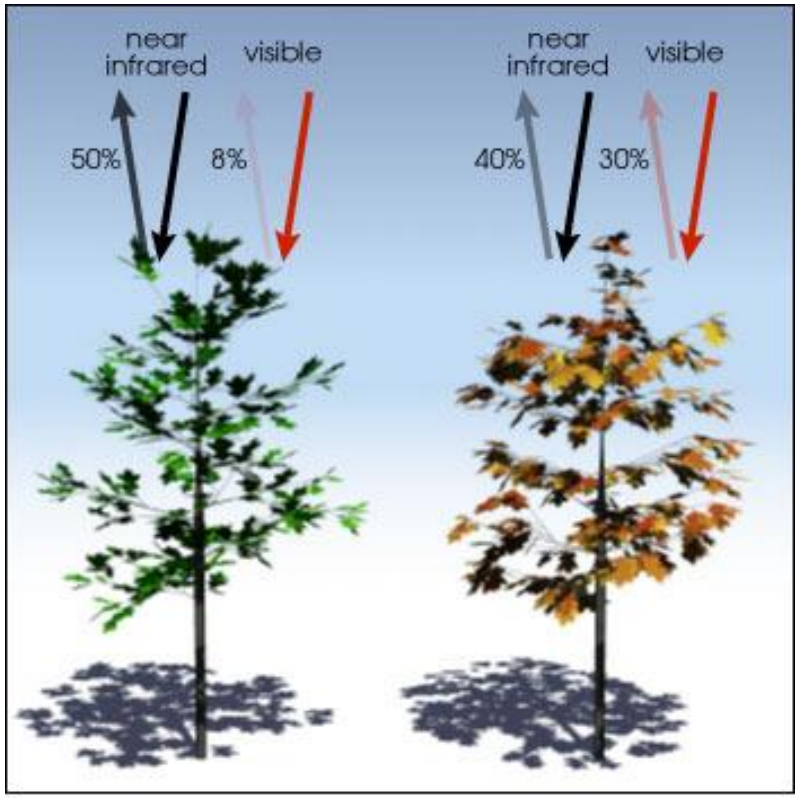


Normalized Difference Vegetation Index (NDVI)

Canopy Reflectance

More green cover:

Higher NIR,
Lower red



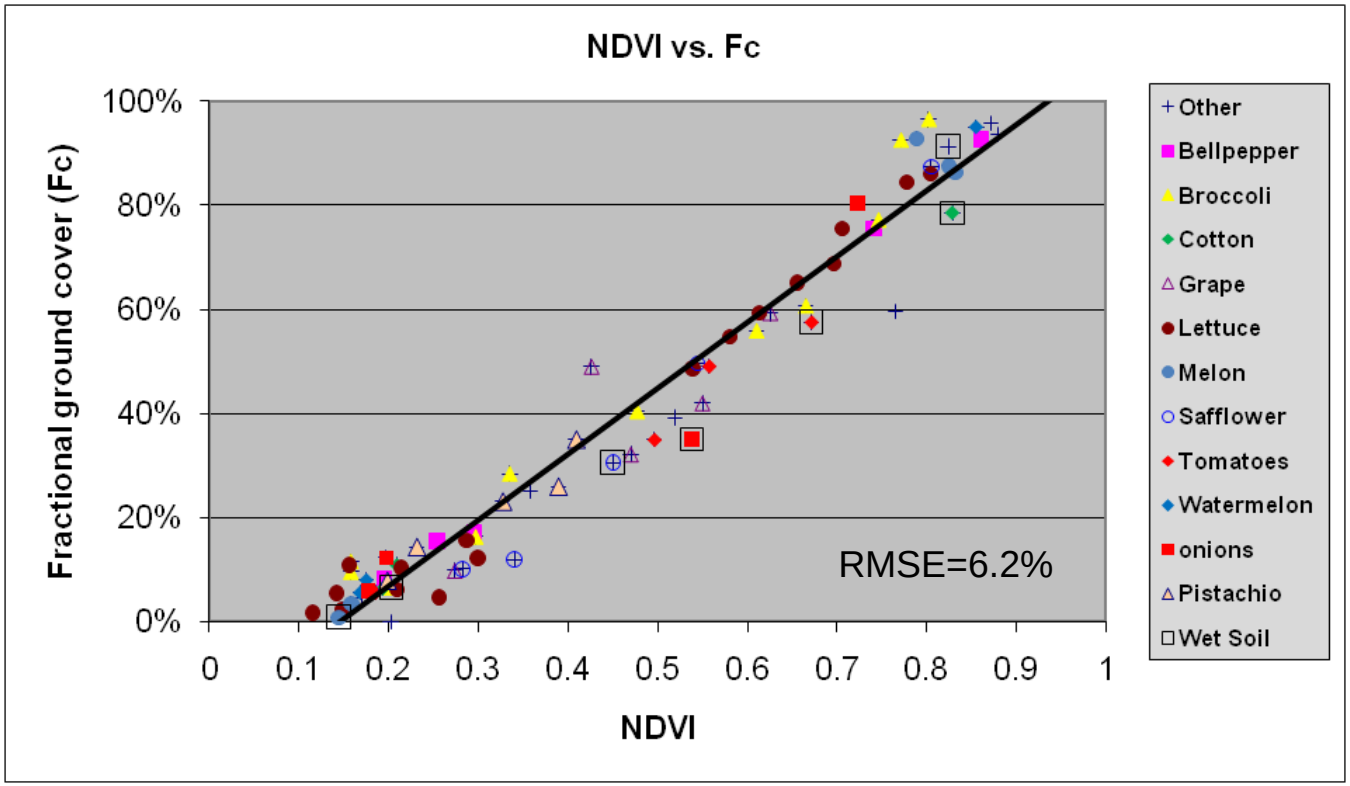
Less green cover:

Lower NIR,
Higher red

Higher NDVI

Lower NDVI

NDVI vs. crop development



-Led by USDA/ARS

-Good relationship NDVI vs. green crop cover shown for several Calif. crops

-Additional testing ongoing in collaboration with UC Cooperative Extension

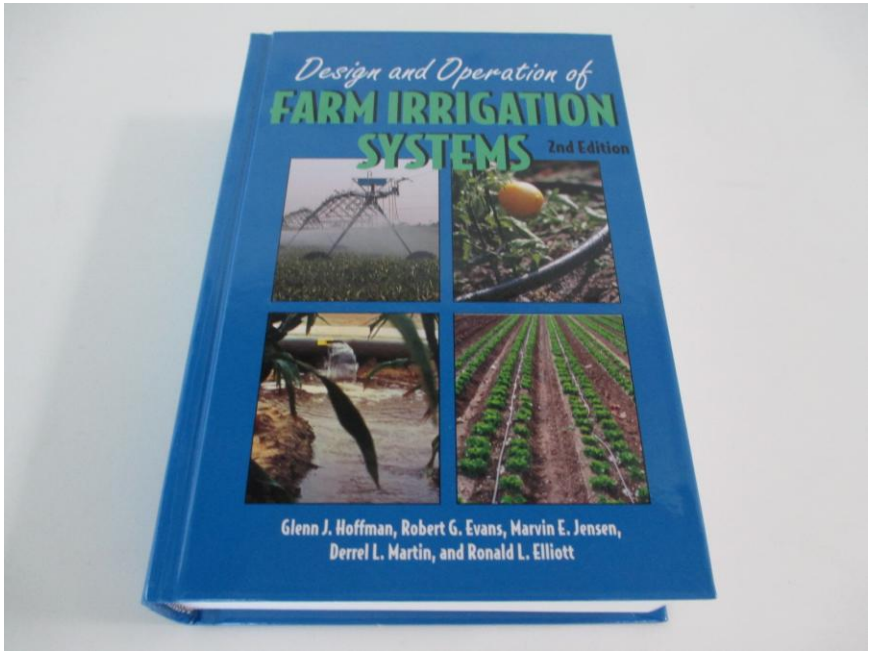
Trout et al., 2008; Johnson & Trout, 2012

ETc drivers

- Crop fractional cover (net radiation)
- Crop height (aerodynamic resistance)
- Stomatal control (canopy resistance)
- Evaporation from exposed soil

FAO-56 (Crop Evapotranspiration: Guidelines for Computing Crop Water Requirements)

Basal crop coefficient (Kcb)



(Amer. Soc. Agric. Bio. Engrs.)

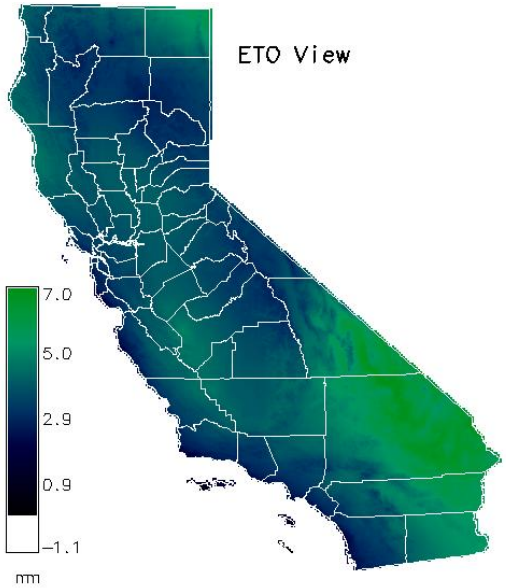
- Fractional cover (and crop height) as basis for crop coeff. estimation
- “Density coefficient” approach

CIMIS reference evapotranspiration

California Irrigation Management Information System (CIMIS)

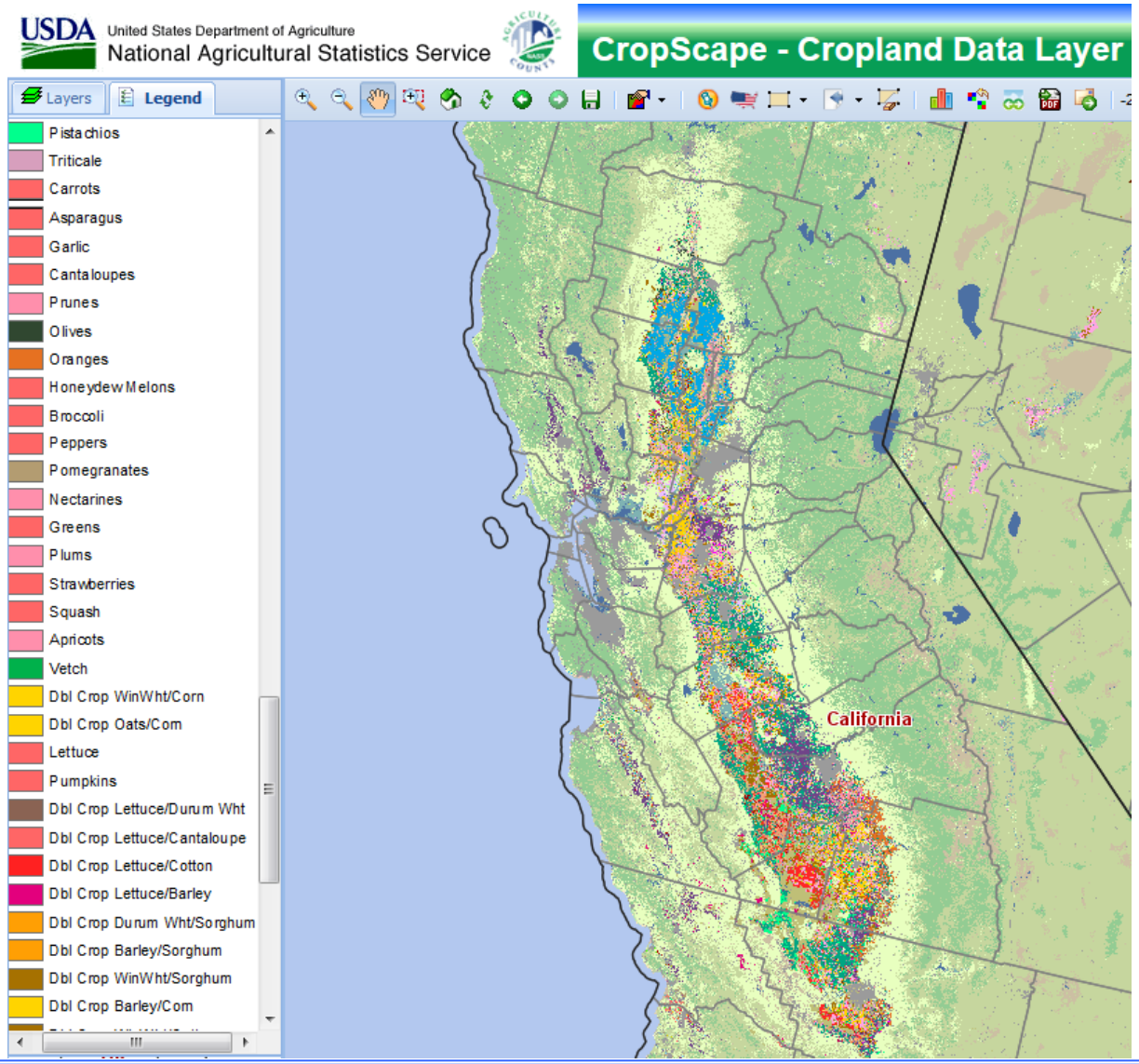
- Calif. Dept. Water Resources
- Operating since 1982
- Statewide network archives daily measurements of ETo
- **Spatial CIMIS** 2km statewide grid, daily
  - GOES geostationary satellite used to modify clear-sky radiation estimates
  - Partnership between CDWR & UC Davis (Hart et al., 2009)

Photo credit: DWR CIMIS



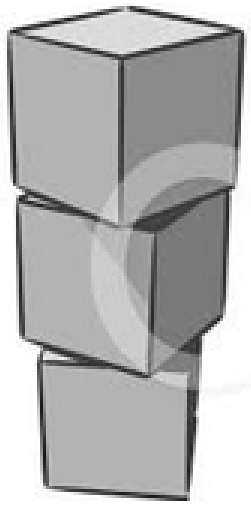
Spatial CIMIS ET_o 13-Oct-2014

CDL (crop type)

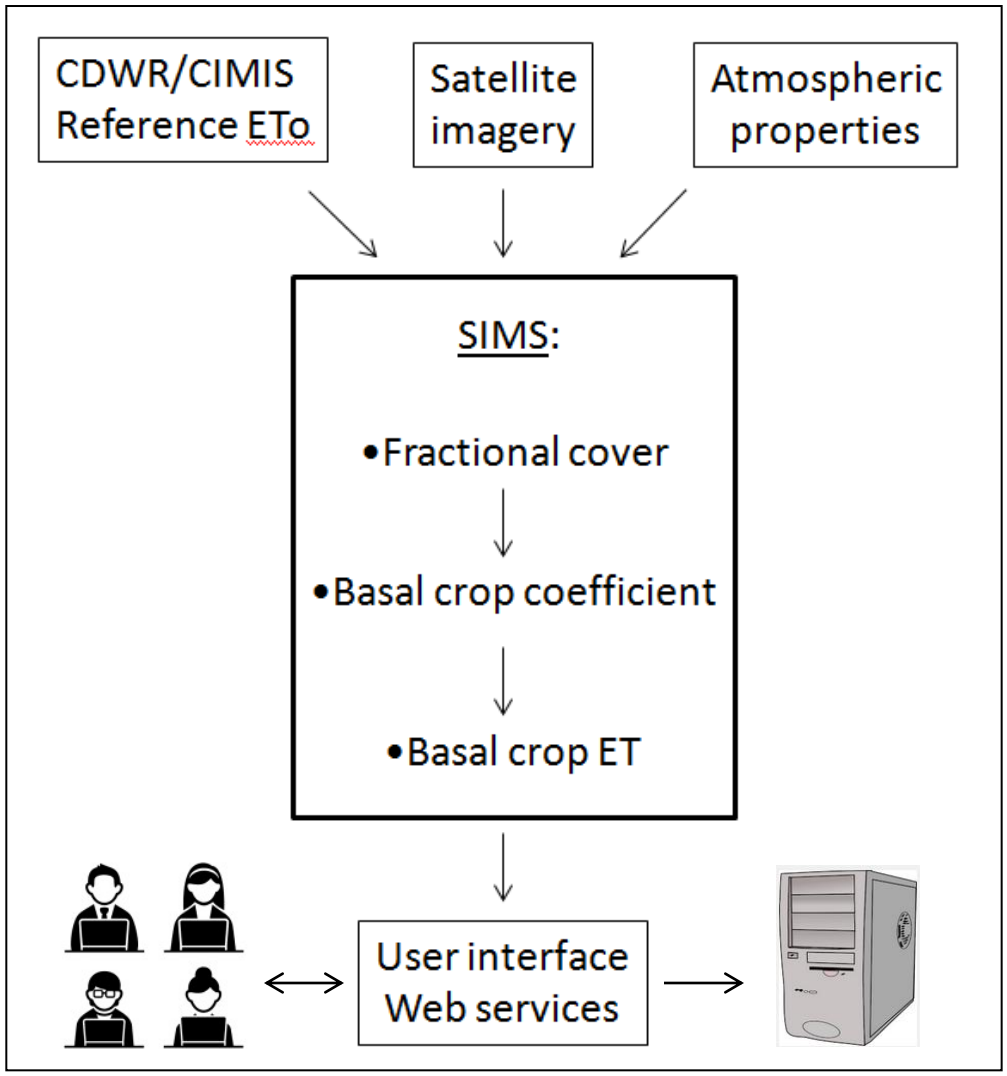


- Landsat + other satellite imagery informed by Farm Service Agency ground data
- >100 crop classes
- Annual update
- Retrospective (year-end)

SIMS

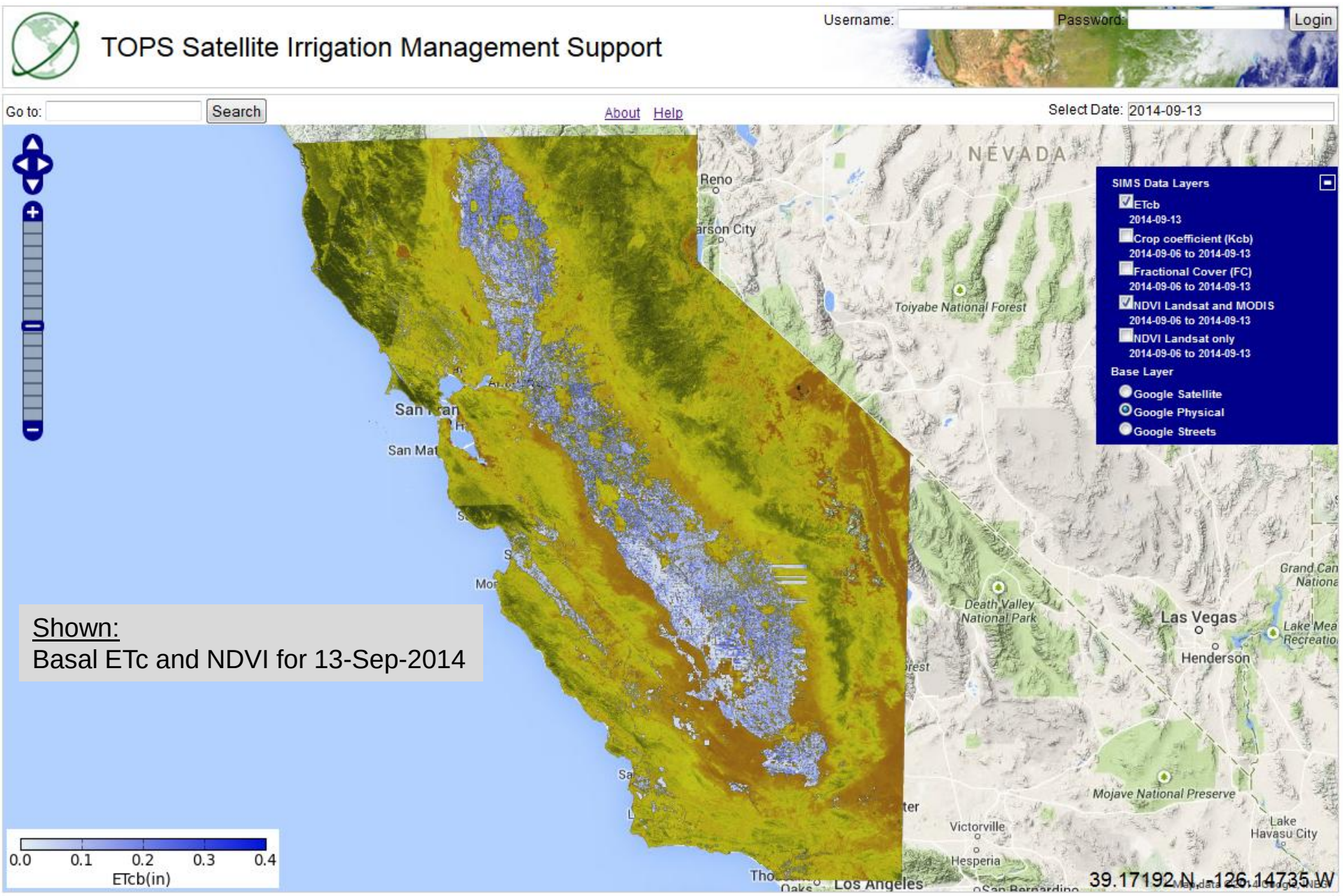


SIMS flowchart



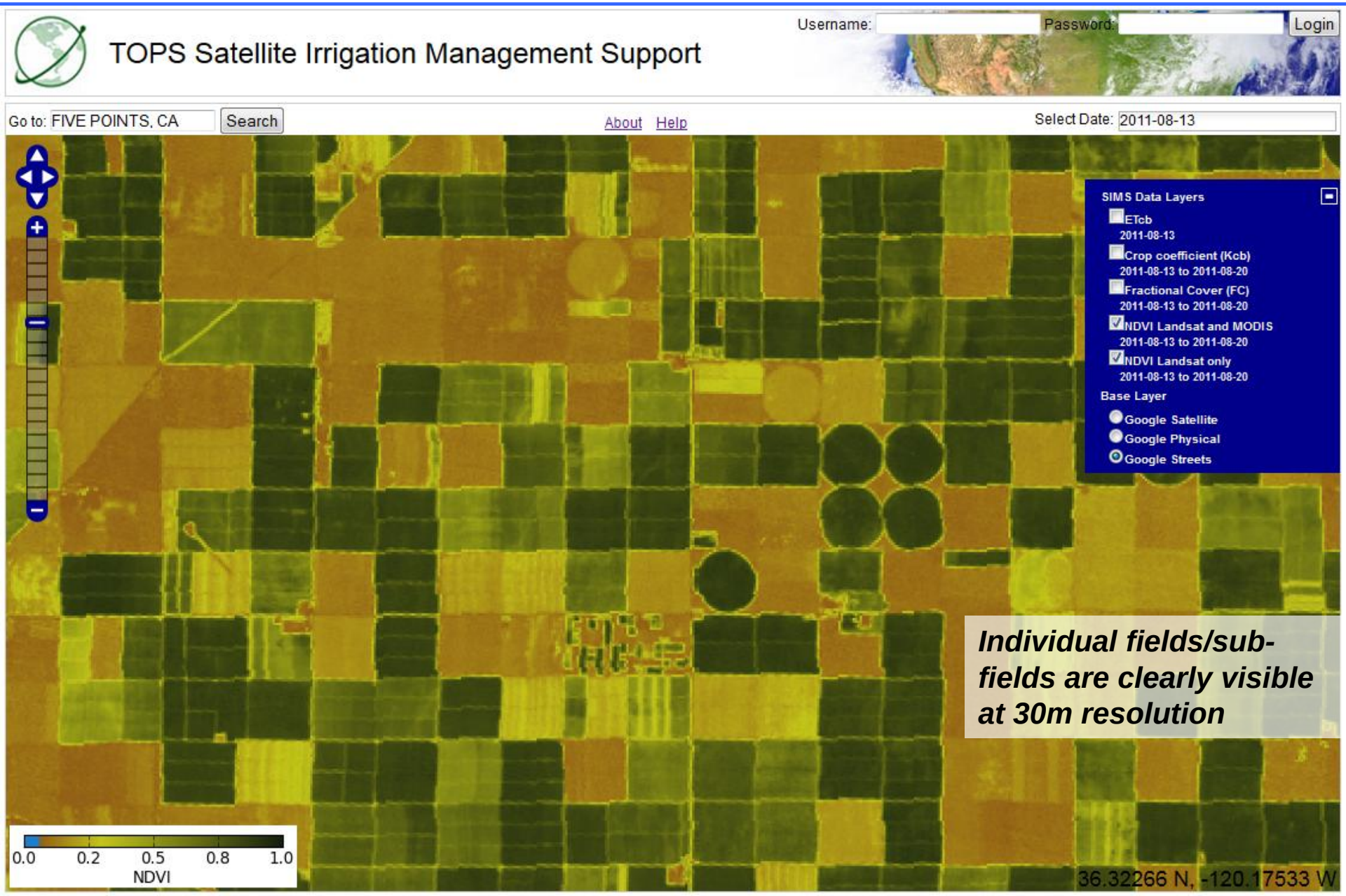
Melton et al., 2012

SIMS NDVI



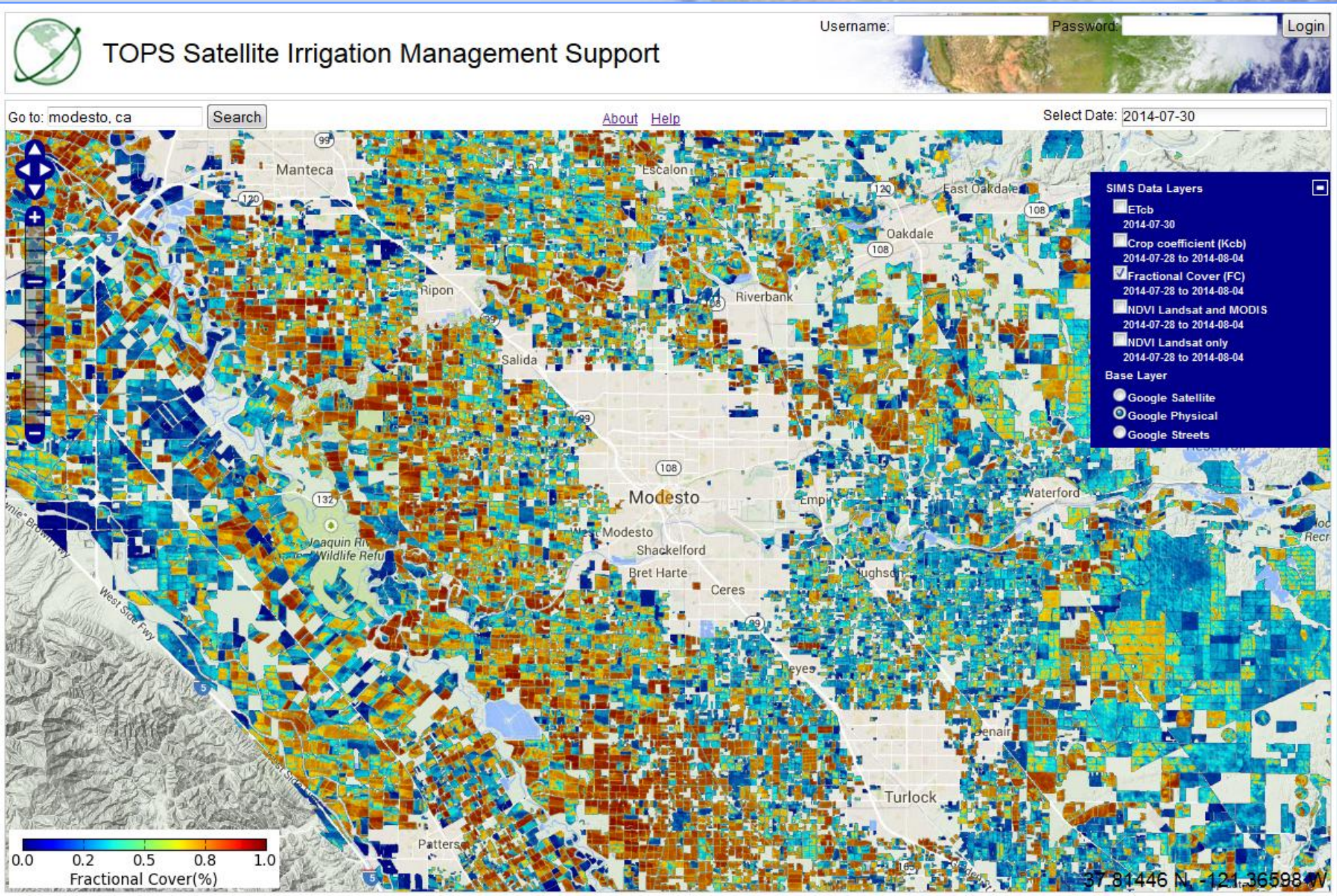
Shown:
Basal ETc and NDVI for 13-Sep-2014

NDVI close-up

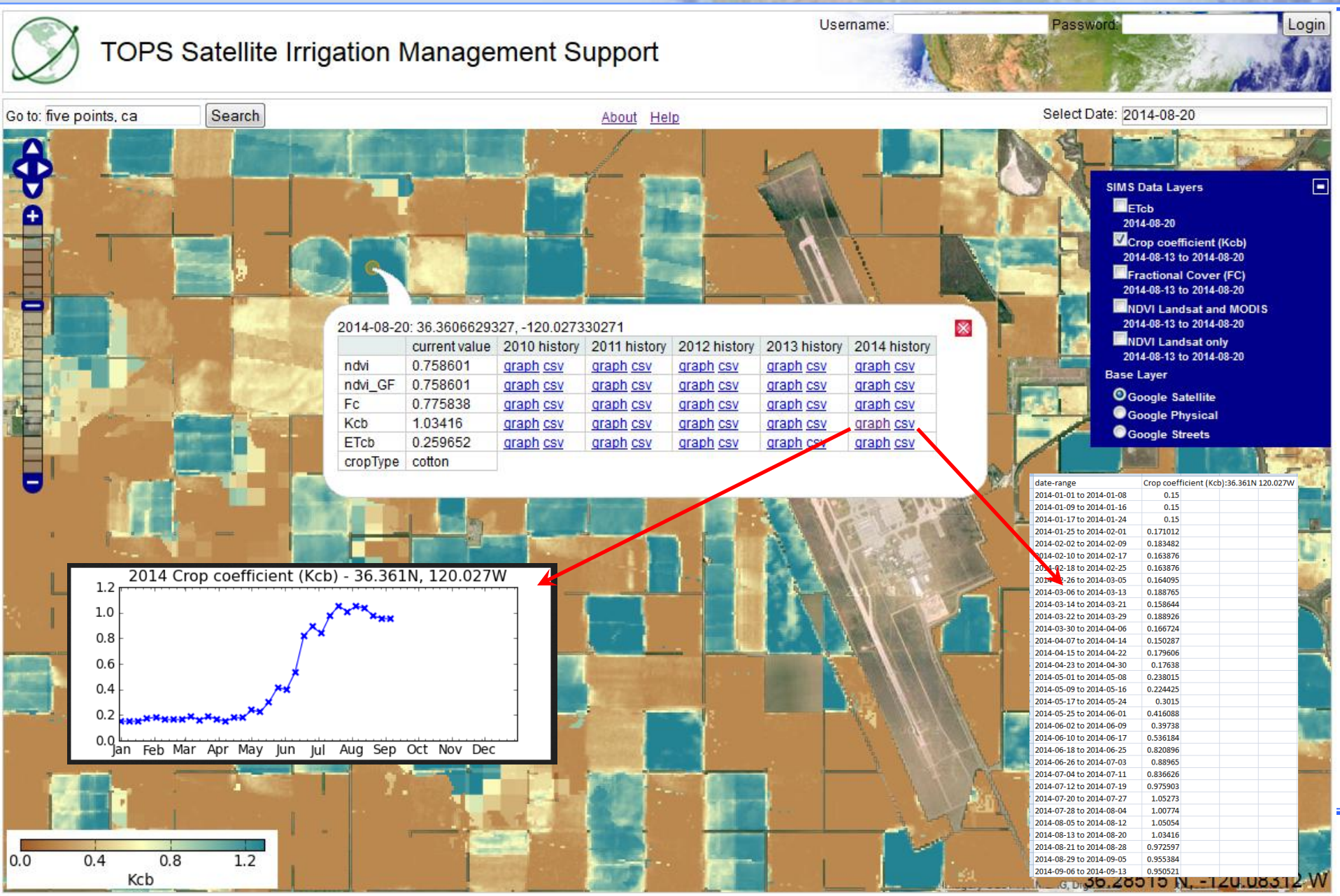


Individual fields/sub-fields are clearly visible at 30m resolution

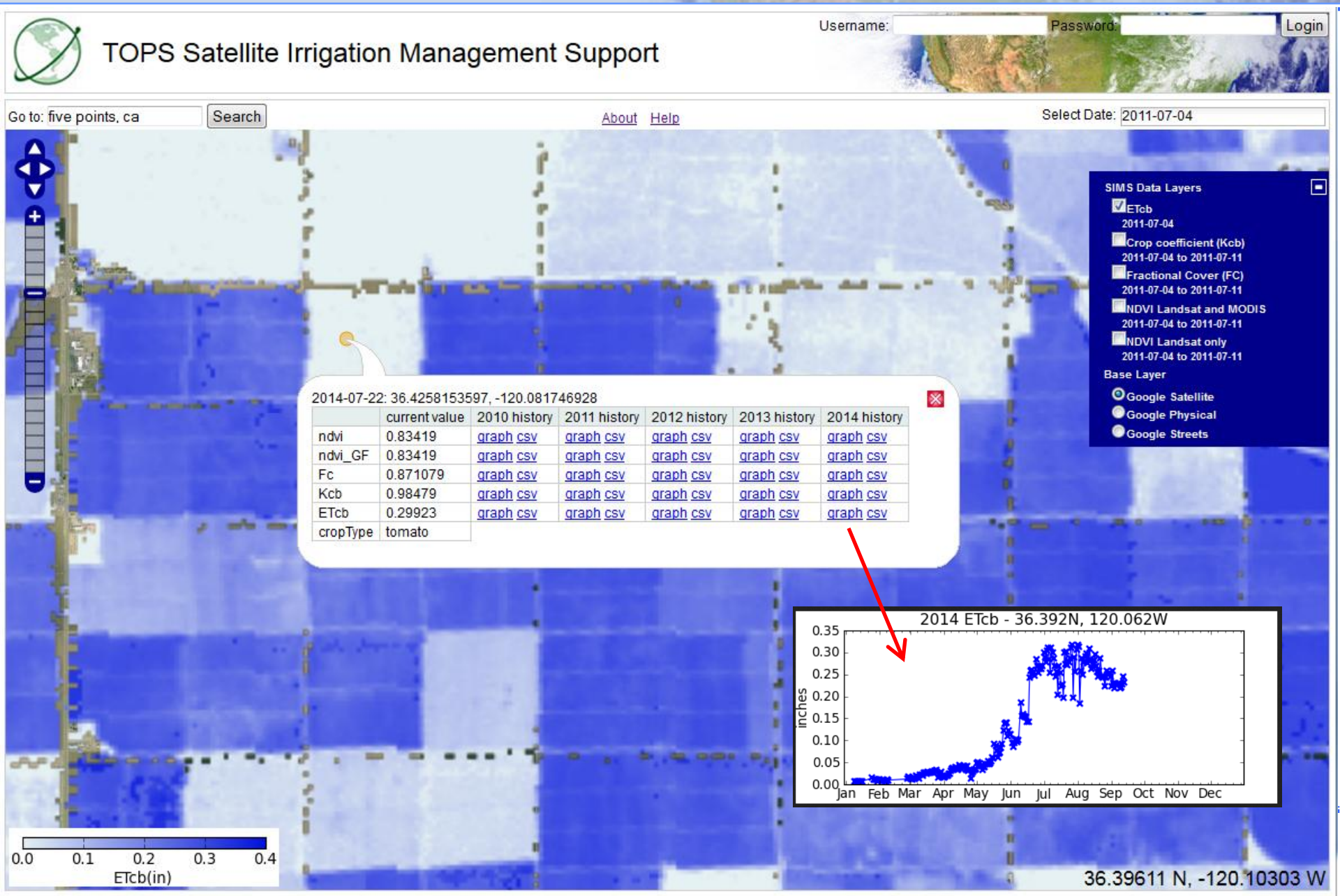
Crop fractional green cover



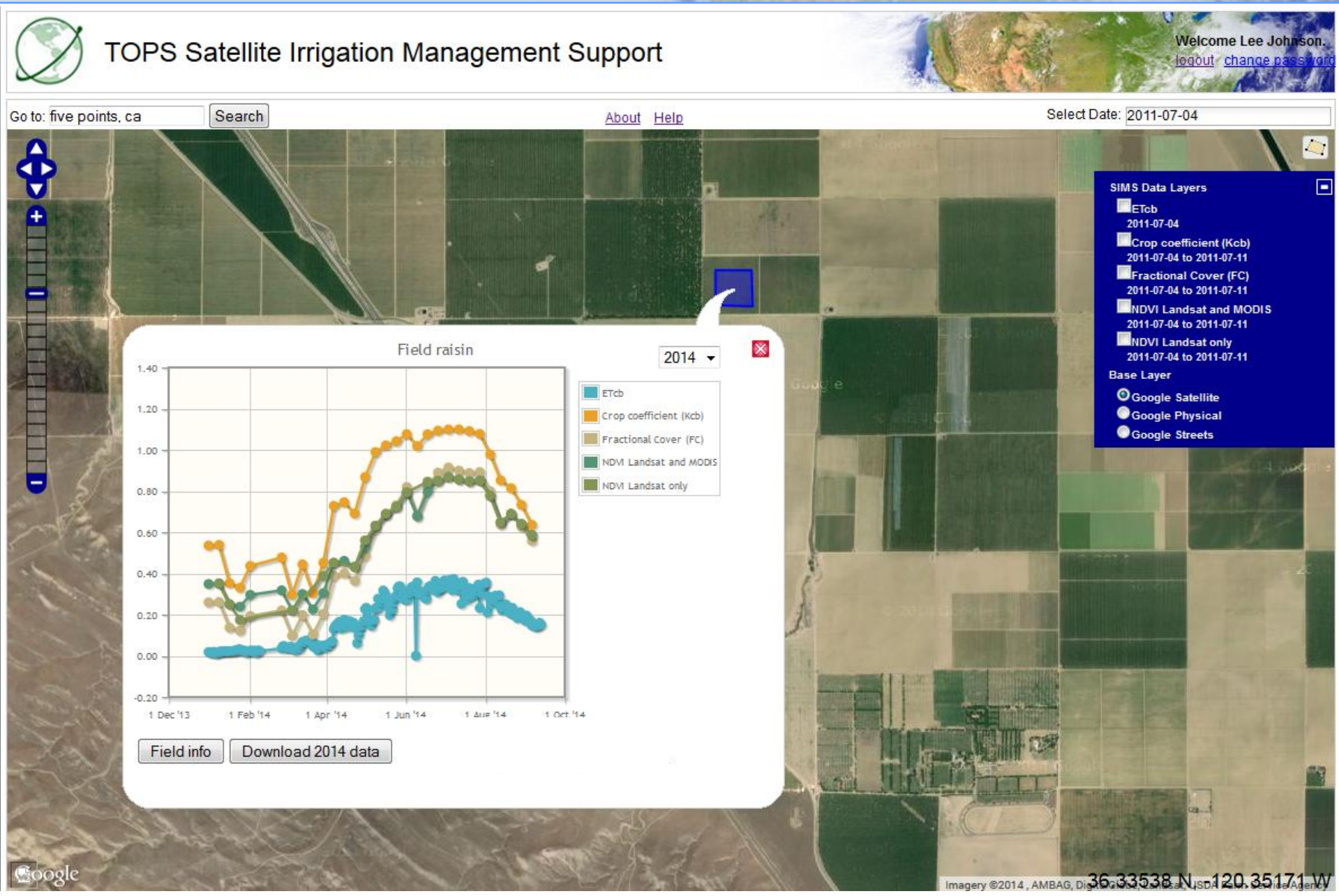
Crop coefficient (basal)



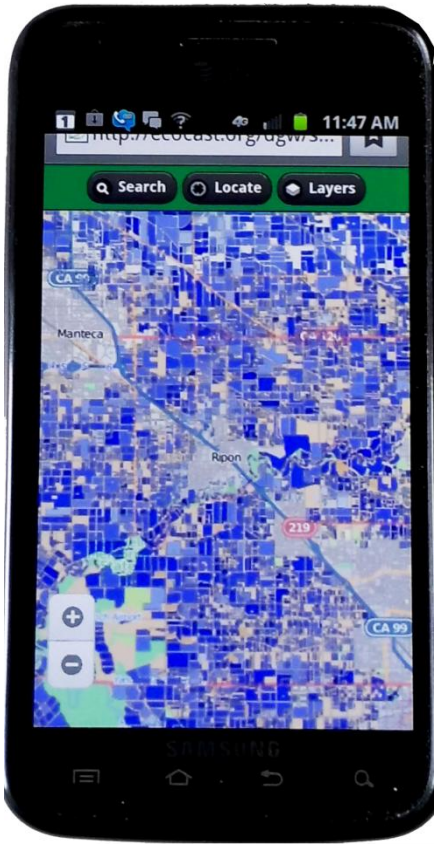
Daily crop ET (basal)

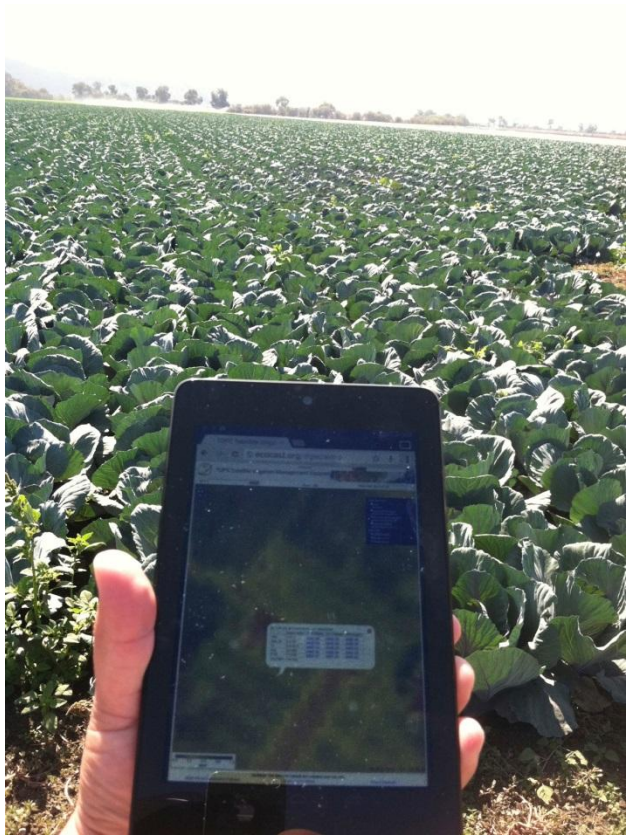


Polygon tool



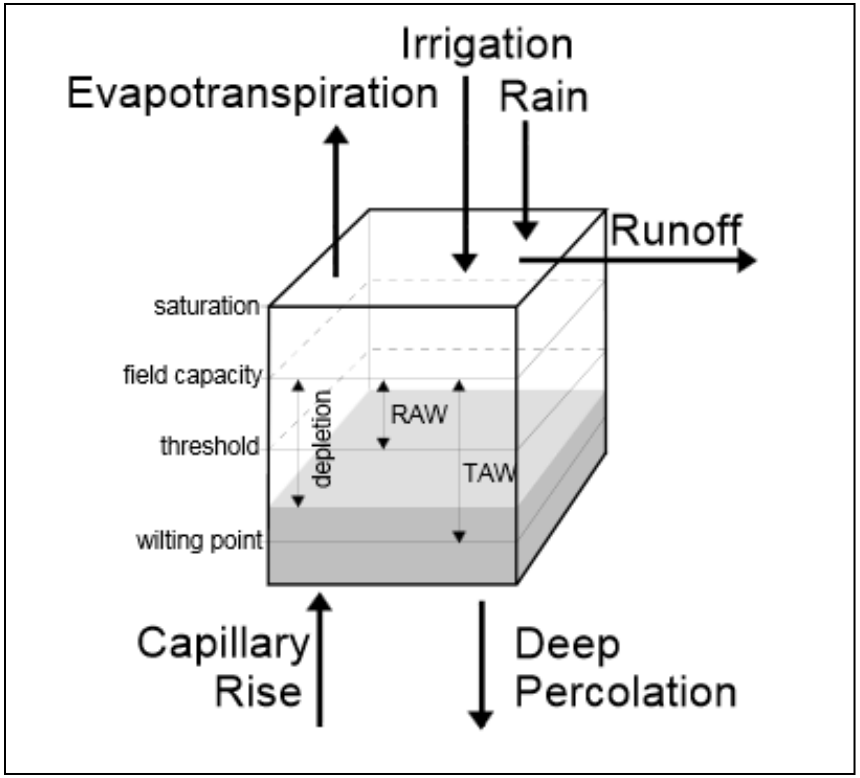
Mobile-optimized interface under development





Calculation of Ks and Ke

Soil water balance model:



- Requires some add'l info:
  - -irrigation schedule
  - -delivery method
  - -soil texture
  - -crop type

- Derive stress & evaporation coeff's: Ks, Ke

- Calculate adjusted ET as:

ETc adj = (Ks*Kcb + Ke)*ETo

FAO-56; ASABE manual

SIMS evaluation

Monitor *seasonal* ET by soil water balance:

$$ET = P + I - D - \Delta S$$

P = precip, I = irrigation
D = drainage below root zone
ΔS = change in soil water content

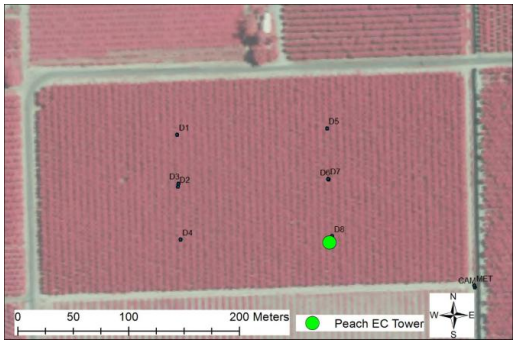
Seasonal ET

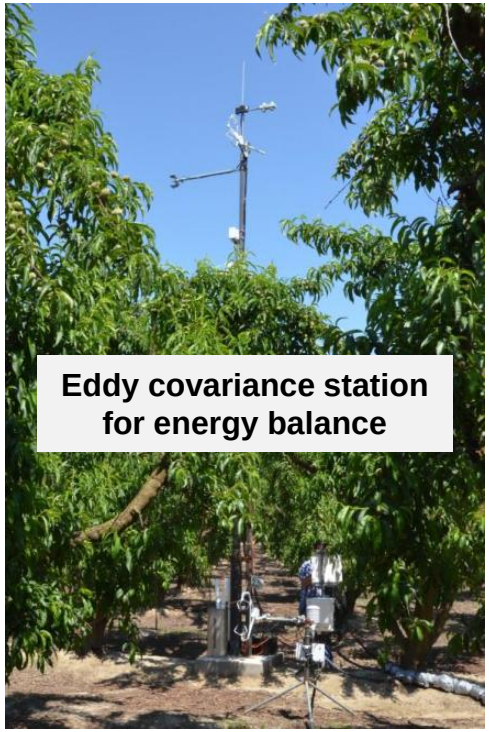
~10-15% error vs. ground measurements of seasonal ET for several crops:

Almond
Garlic
Lettuce
Melon
Peach
Tomato
Wheat
Cotton*
Grape (raisin)*
Grape (wine)*
Orange*

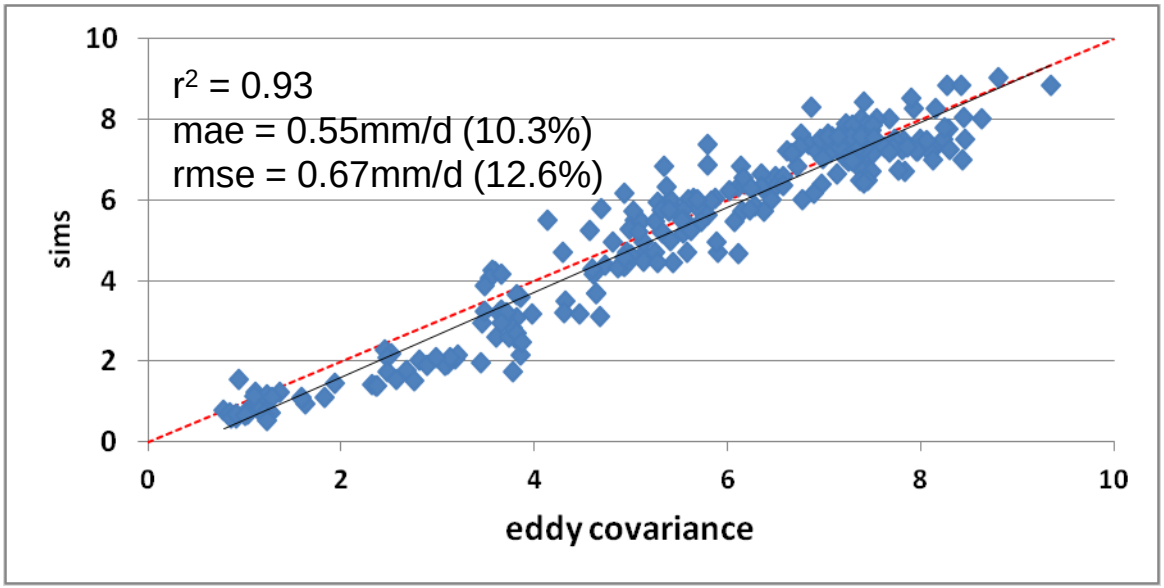
**after post-processing with soil water balance model*

Daily ET





Daily ETc (mm) for SJV peach orchard, 4/6/2012-12/3/2012



Field data courtesy Dr. Ray Anderson, USDA/ARS

Example applications

- ET-based irrigation scheduling
- Calculation of agricultural water use fractions
- Fallowed area mapping

Summary

- Background, concepts

- Remote sensing of ET (SIMS example)

Applications:

- ET-based irrigation
- Water use fractions
- Fallowed area mapping

Acknowledgments: F. Melton, K. Post, A. Guzman, J. Shupe, C. Lund, C. Rosevelt
Sponsors: NASA Earth Sci, USDA/CDFA-SCBGP, Cal DWR, CSU-ARI